

# OPTIMAL LOAD FOR MAXIMAL POWER OUTPUT DURING SQUAT JUMP TRAINING

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## Introduction

The relationship between force, velocity and power output has been studied in bundles of muscle fibers<sup>1</sup>, single joint movements<sup>2</sup>, and multijoint movements such as vertical jump<sup>3</sup>. The majority of prior research concurs that the force capability of muscle in concentric actions decreases with increasing velocity of shortening and that maximum power output is produced at approximately 30% of maximum isometric force (MVC)<sup>4-6</sup>. The purpose of this study was to determine in jump athletes with extensive training background the load at which power output during a squat jump is maximized and relate this optimal load to maximal strength and body weight. Also, comparisons were made between men and women with regard to strength and power output.

## Methods

Sixteen men and twelve women, all NCAA Division I volleyball players were recruited for this investigation. Each signed an IRB approved informed consent document. The subjects were asked to attend two test sessions. On day one, 6-repetition maximum load (6RM) on a free weight barbell back squat was determined and used to estimate 1RM strength. On the second day of testing, at least 7 days later, the subjects performed sets of three squat jumps with a load of approximately 30% of 1RM. The load was then increased or decreased until the barbell load that produced the maximum power output was isolated. Vertical ground reaction force was measured using a force platform (Kistler Quattro Jump) mounted under a Smith machine in which the athlete jumped. A linear transducer (Ballistic Measurement System) was used to measure bar displacement. Force and displacement were recorded at 500 Hz using a computer and velocity calculated using the finite difference technique. Velocity and force data were multiplied together to obtain instantaneous power time data. The absolute peak in power output over the three repetitions was recorded for further analysis. Means and standard deviations for peak power, estimated 1RM, BW, and various ratios of optimal load to strength and body weight calculated. One-way ANOVA was applied to determine if there were any differences between men and women. A criterion significance level of  $p \leq 0.05$  was used for all statistical comparisons.

## Results

**Table 1.** Mean (SD) 1RM strength, power and power ratios for women and men volleyball players and the results of the one-way ANOVA comparison of gender.

Variable	Women (n=12)	Men (n=16)	F (p)
body mass (kg)	69.3 (6.7)	88.0 (9.0)	29.4 (0.000)
estimated 1RM (kg)	76.3 (17.3)	134.5 (17.1)	68.5 (0.000)
1RM/BW (%)	114 (28)	151 (25)	9.29 (0.007)
optimal load (kg)	13.0 (1.8)	27.8 (2.0)	371 (0.000)
peak power (W)	3740 (386)	5981 (727)	80.1 (0.000)
power/BW (W.kg <sup>-1</sup> )	54.1 (3.8)	68.3 (8.7)	23.7 (0.000)
Load/1RM (%)	18.03 (0.05)	21.13 (0.03)	2.64 (0.122)
Load/BW (%)	19.07 (0.06)	31.82 (0.03)	64.4 (0.000)
[load+BW]/[1RM+BW] (%)	56.7 (0.07)	52.7 (0.04)	2.26 (0.150)

## Discussion

The aim of this study was to relate the load at which maximal power was produced to the strength and body weight of the athlete. Although previous research<sup>4-6</sup> has reported a load of 30% MVC to be optimal, the actual load that the athlete jumped with in this study (load+BW) expressed as a percentage of the load lifted during a 1RM squat (1RM+BW) was considerably higher at 54%. This may have been due to an overestimation of 1RM by the method used. When the optimal load was expressed as a percentage of 1RM it was much lower than 30%. Given the marked differences depending on how the ratio is calculated it may be better to determine the optimal load and use this in training and for monitoring progress. An important practical implication of this study is that the optimal load varies between athletes and as a factor of gender therefore it would be useful to determine the exact load where power is maximized for training purposes. Differences between women and men were considerable with the women exhibiting much lower power to body mass ratio. It is suggested that this was due primarily to the low strength, both absolute and relative to body weight, for women compared to men. Also, women may especially benefit from squat strength training to address the imbalance between strength and body mass. If this is addressed then power output should increase and thus jump height.

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